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DEVELOPMENT AND IMPLEMENTATION OF A RCG BITMAP LOGGER

- FEASIBILITY STUDY -

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GLOSSARY

ASCII:	*American Standard Code for Information Interchange*
CPU:	*Central Processing Unit*
DND:	*Department of National Defence*
DREO:	*Defence Research Establishment Ottawa*
GB:	*Gigabyte*
GUI:	*Graphical User Interface*
KB:	*Kilobyte*
LSS:	*Logistics Support Site*
MTBF:	*Mean Time Between Failures*
NRE:	*Non-Recursive Engineering* costs
NWSSC:	*North Warning System Support Centre*
PC:	*Personal Computer*
RCG:	*Remote Controller Group*
ROCC:	*Region Operations Control Centre*

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1. PURPOSE

The Department of National Defence is responsible for the operation and maintenance of the North Warning System within Canadian territory. The North Warning System consists of multiple, stand-alone radar sites located in the Canadian Arctic. These sites are serviced from Logistic Support Sites (LSS) and North Warning System Support Centres (NWSSC) while the operation and monitoring is conducted from a Region Operations Control Centre (ROCC).

The monitoring of the various radar sites is performed with automatic test equipment located at each site. Data from various sensors and monitoring points within the radar is acquired locally and transferred to the ROCC through RF and telecommunications links. The ROCC acquires data from all radar sites. Data is interpreted locally by trained personnel responsible for taking proper actions following data analysis.

Acquired data consists of multiple data streams, tables, and other status reports presented on computer monitors, stored in RCG local memory and on disk, and archived on tape or printed on paper. Of all these reports, one is a bitmap providing a graphical status representation of the multiple electronic components within the radar. The bitmap provides valuable information on the radar functional status and on the corrective actions to be taken.

The bitmaps are received at the ROCC and stored in RCG local memory. The memory has a first in first out buffer that can hold up to 64 bitmaps per site. The bitmaps in the buffer can be printed upon request from the operator. Once the buffer reaches its full capacity, bitmaps are lost. This can be a major inconvenience if an event must be traced back in which case there is a significant probability that the required bitmap is lost if the request to print comes too late.

1.1 OBJECTIVES

The Department of National Defence is interested in logging all bitmaps at the ROCC for future retrieval. This would eliminate the loss of critical information and simplify diagnostics of the radar. The goal of this document is to explore the various ways in which the bitmap data could be logged and formulate recommendations.

More specifically, MultiDev shall meet the following objectives:

- describe the configuration of a bitmap logger capable of storing, displaying and printing the bitmaps.
- identify all possible configurations for intercepting or transferring the bitmaps to the logger.
- propose the viable options and analyze each one.
- explain the risks associated with the addition of a logger, depending on the selected configuration
- analyze the costs associated with the development of a logger.
- perform a multicriteria analysis to determine the best possible option.

1.2 CONSTRAINTS

In defining the best possible implementation of the bitmap logger, some constraints must be identified to select a viable solution that will maintain the functionality of the RCG. In other words, the logger shall be capable of manipulating the bitmaps without impacting the RCG operation. As well, the proposed solution for a bitmap logger implementation must achieve an equal or better performance than modifying the RCG itself. If a bitmap logger is to be added in the system at the ROCC, the following system limitations or restrictions are necessary:

1. The logger shall not modify the existing operation of the RCG. None of its functionality and reliability shall be altered.
2. The CPU time of each computer that form part of the RCG shall be maintained within a reasonable limit (< 50% duty cycle). If the CPU duty cycle exceeds those limits, the newly developed software could prevent other programs from executing normally.
3. With the addition of the data logger at the ROCC, secured system access shall be maintained to prevent unauthorized intrusion at the RCG.
4. The bitmaps logged at the ROCC shall be identical to the ones stored at the RCG. It is highly recommended to intercept integral bitmaps instead of fault masked patterns.
5. The logging function at the ROCC shall be automatically performed and shall be updated at the present rate. No operator shall be required to activate the function or command the RCG to send the bitmaps to the logger.
6. The logger shall be able to reliably intercept the bitmaps in a passive manner, without missing data or requesting to retransmit.

1.3 METHODOLOGY

The current system will be analyzed to determine how bitmaps are currently manipulated within the RCG. Based on the current RCG configuration, a list of potential solutions to extract the bitmaps will be drawn. If a solution is not considered to be viable because it will not meet the constraints listed in section 1.2, the reasons are explained in the same section and it will not be given any further consideration.

The viable solutions will be analyzed in details, based on these criteria:

- RCG integrity
- RCG security
- RCG reliability
- implementation complexity
- modifications to the system
- bitmap format extraction

Finally, other criteria will be analyzed separately:

- the risks associated with the operation of the RCG in conjunction with the bitmap logging function.
- the implementation costs of the logger and the modifications to the RCG.

2. FUNCTION ANALYSIS

2.1 ACTUAL BITMAP LOGGING FUNCTION

The RCG stores bitmaps as they are received from the radar sites via the X.25 ports. Each site has a 64 bitmap deep buffer which discards the 64th bitmap as a new one is coming in. The bitmap logging function does not retain permanently the bitmaps and bitmaps that are not printed while they reside within the RCG are deleted and lost.

An operator can access the last 64 bitmaps via a terminal. The operator can examine each report of the bitmap by selecting the different report sheets. The operator can also print the bitmap reports by selecting the print function.

The printing function is not automatic. An operator must select a bitmap and initiate a print function in order to generate a hard copy. There is no mechanism to transfer bitmaps or permanently store bitmaps other than printing them. No bitmap manipulation and analysis is possible using the RCG computers.

The hard copies generated by the bitmaps represent a fair amount of paper which must be stored in order to maintain a copy of a bitmap. The amount of paper required to build a history of a radar site is significant.

One printer per computer is required. This represents 8 printers for the complete RCG groups.

2.2 PROPOSED BITMAP LOGGER

The bitmap logger to be implemented at the ROCC collects information generated by the radar sites and compiled by the RCG. The logger must be able to intercept data generated by each site in the same format as when printed on the RCG printers. The bitmap report is seven pages long and an example is provided in Appendix A.

The logger shall provide data interfaces to intercept all data links that transfer bitmap information. The number of data links depend on the type of data intercept chosen for this application. For example, if the RCG printer port is chosen, there will be 8 data links (see section 3.2). Figure 1 illustrates an example of a bitmap logger with 8 data links.

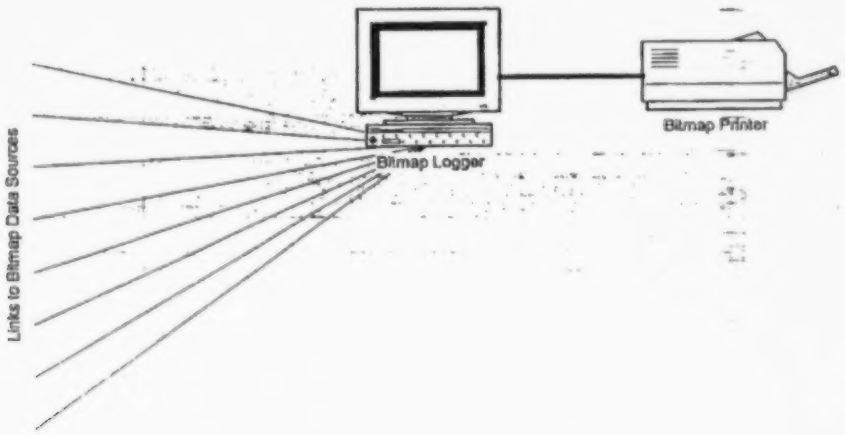

Figure 1 - Example of a Bitmap Logger

The logger shall be able to automatically retrieve and store the bitmaps without a specific action to be undertaken by an operator. It shall be able to connect to the RCG and automatically intercept the bitmaps, as long as the RCG is operational. Since there are four computer pairs (the main and back-up computers), the bitmaps generated by all eight computers shall be retrieved and stored.

Once the bitmaps are intercepted by the logger, they are permanently stored on a hard disk and backed up on a permanent storage media. The bitmap number is verified and duplicate bitmap copies are deleted to avoid having multiple copies coming from the same computer pair.

The bitmap program can offer many search options such as:

- search for a bitmap number and site ID
- search for bitmaps generated on a certain date
- search for bitmaps generated by certain sites

In addition to the search capability, the logger can also offer other functions such as the interpretation of the bitmaps. By having the bitmaps separate from the RCG, it is now possible to develop code that will allow the analysis of the radar faults and suggest possible causes.

A block diagram of the logger operations is presented in Figure 2.

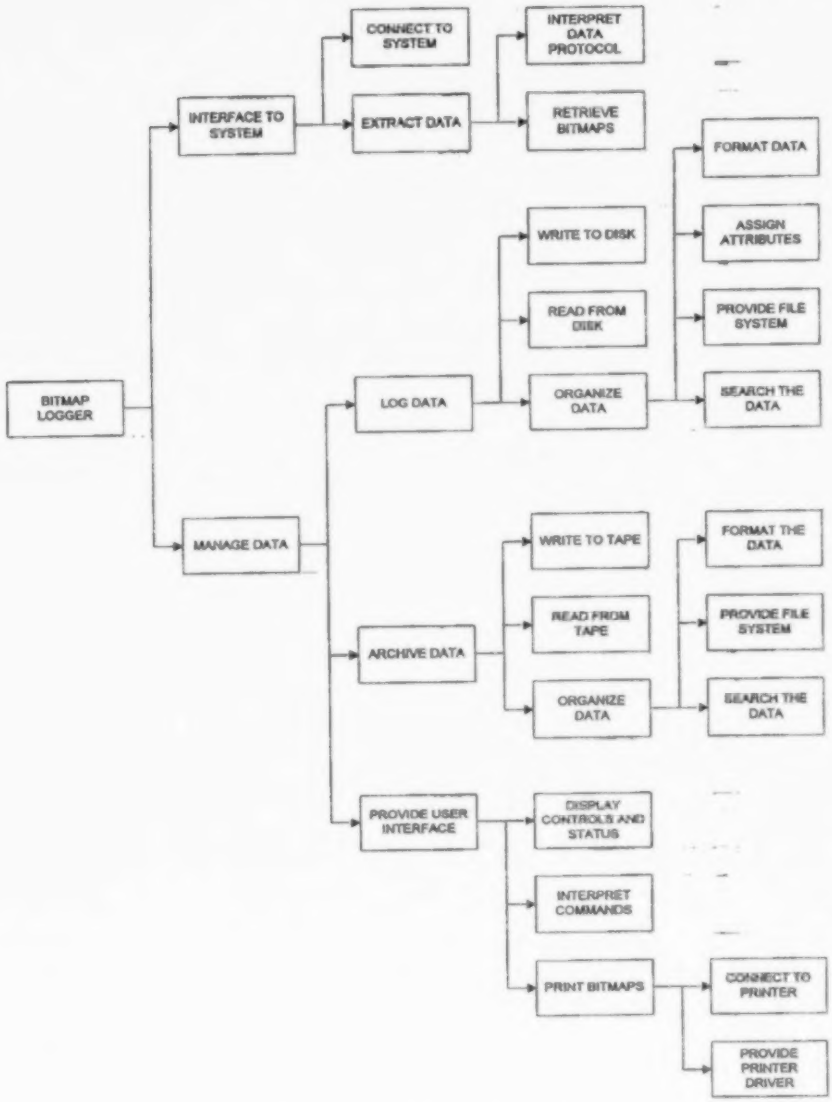

Figure 2 - Block Diagram of the Bitmap Logger Functions

3. PROPOSED SOLUTIONS

Based on the information that was provided to MultiDev, a number of possible approaches were developed and are described below. Seven potential options were found. Of those, three were identified as viable and four others were rejected. In addition to the solutions, the considered factors for retaining or rejecting a solution are explained at the end of each option.

3.1 POSSIBLE APPROACHES

The RCG system is responsible for collecting, storing, displaying and printing the radar information coming from all radar sites. Each computer pair - a main computer and a back-up computer - can monitor (and control) up to 10 radar sites. A total of four computer pairs are used in the system. The bitmap information is included in the radar information and is extracted from it.

The radar information is sent to the computer group via a large number of X.25 links, transporting the bitmaps as well as other radar related information. Once data is stored onto the RCG, the bitmap information can be printed to the printer via a RS-232 serial link. The data is also exchanged between the main computer and the back-up computer via an Ethernet link. See Figure 3 for the RCG computer components and Figure 4 for the RCG computer configuration.

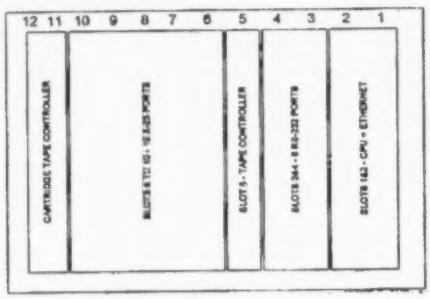

Figure 3 - MicroVAX Computer Slot Allocation

A new bitmap is generated every time there is a change in the radar status. Although the bitmaps are stored in the computers, only the last 64 entries per radar site are kept. When a new bitmap is received, the oldest bitmap on the list is discarded. MultiDev will solve this problem by implementing a mechanism to permanently store all bitmaps at the same location.

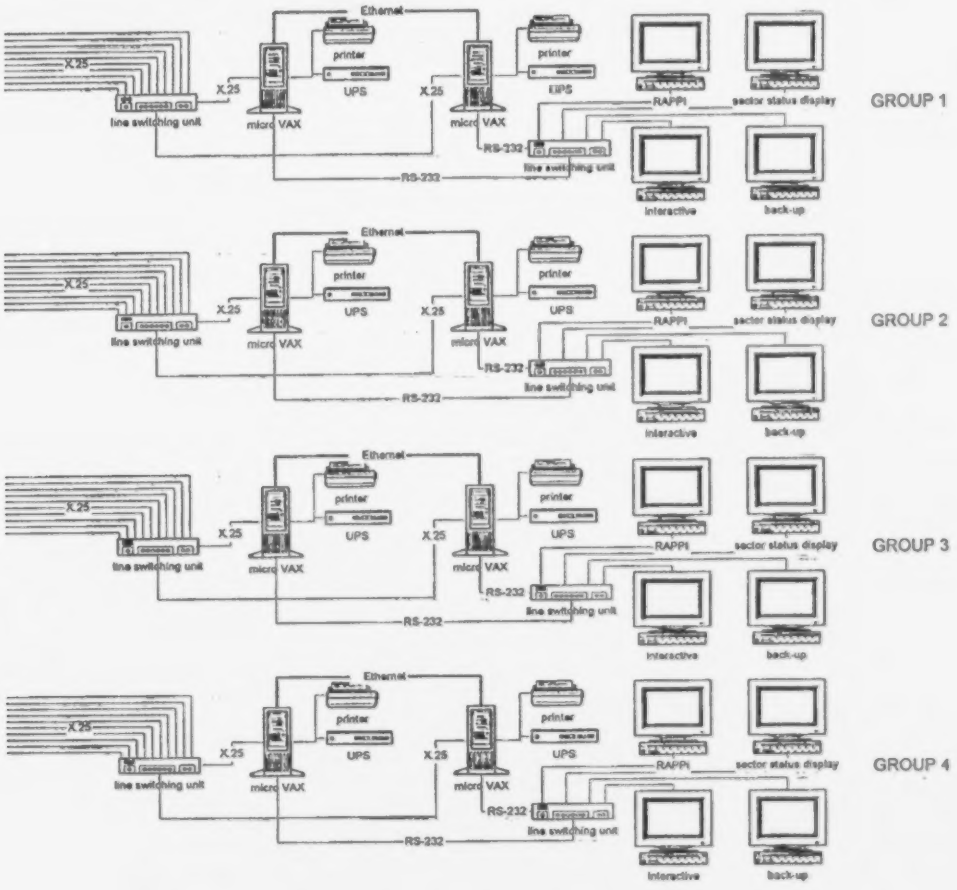

Figure 4 - RCG Computer Configuration

In order to store the bitmap information on another computer, the data must be intercepted when it is being transferred to the RCG or generated by the RCG. A total of seven configurations are possible for the data intercept:

- the printer port line is intercepted when it is printing the bitmaps (section 3.2).
- an unused serial port is configured to generate the bitmaps (section 3.3).
- the bitmap logger is connected to the Ethernet link and intercepts the bitmaps being exchanged between the main and the back-up computers (section 3.4).
- the bitmaps generated by the radar sites are intercepted on the X.25 lines (section 3.5).
- an available X.25 line is configured to generate the bitmaps (section 3.6).
- the unused tape back-up port is configured to generate the bitmaps (section 3.7).
- an additional interface card is inserted into the RCG to generate the bitmaps (section 3.8).

The seven configurations are described in the following sections.

3.2 PRINTER PORT

The printer port is a standard RS-232 serial port operating at 9600 baud and connecting to the printer. A total of 8 printers are required: four computer pairs (main computer and back-up computer), monitoring a total of 40 sites.

The bitmaps being transferred to the printers are exactly in the same format to be logged. Therefore, the logging process is straightforward in terms of data formatting. However, 8 connections are required to ensure that all bitmaps are logged.

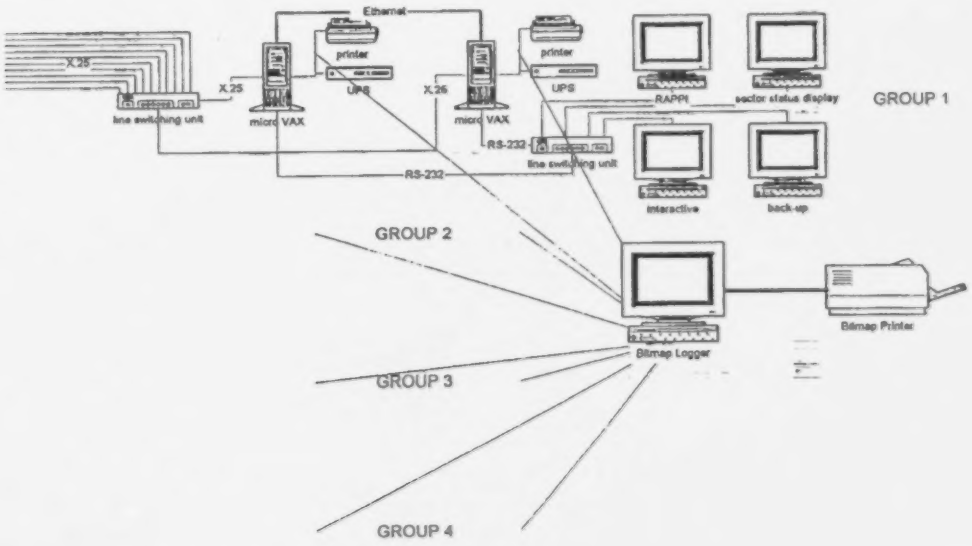

Figure 5 - Printer Port Solution

The logging process would not be automatic since the hard copies are generated on demand only. The bitmap logger requires that an operator type the print command in order to retrieve the information from the serial link. To avoid this situation, a modification to the RCG software must be made to automate the printing process.

Two methods are possible for intercepting the information: by tapping the line or by inserting the logger in between the computer and the printer. In the latter case, the serial port no longer connects directly to the printer and the logger needs to retransmit the bitmap to the printer. In addition, some control codes have to flow back from the printer to the computer. The logger shall be able to retransmit these control codes as well.

The bitmap logger shall be able to receive information coming from 8 RS-232 links, without hardware or software flow control, because it is intercepting the data flow and cannot temporarily suspend the transfers.

3.2.1 Evaluation

MultiDev believes this is a viable option for the following reasons:

- The number of links and physical connections to the bitmap logger is reasonable (8).
- Since data is intercepted, the logger should intercept and store 8 data path simultaneously. The logger interfacing capacity will probably not be exceeded because the number of data paths is limited.
- The RS-232 protocol is very simple and limited to start and stop bits.
- The bitmap information is complete once it is sent to the printer.
- Minimal software code needs to be written on the RCG computers.

3.3 UNUSED SERIAL PORT

As for the printer port solution, it is possible to use one of the two available serial ports for transferring the bitmaps to the logger. The port set-up would be the same as for the printer port, except that this port would be dedicated to the logger, with the capability to implement hardware or software flow control. However, this solution is not automatically implemented since the code on the main and back-up computers would have to be rewritten to duplicate the bitmap printing routines. The code would be similar to the print bitmap functions, except that the transfer to this port would be automatic, not on demand, each time a new bitmap is generated.

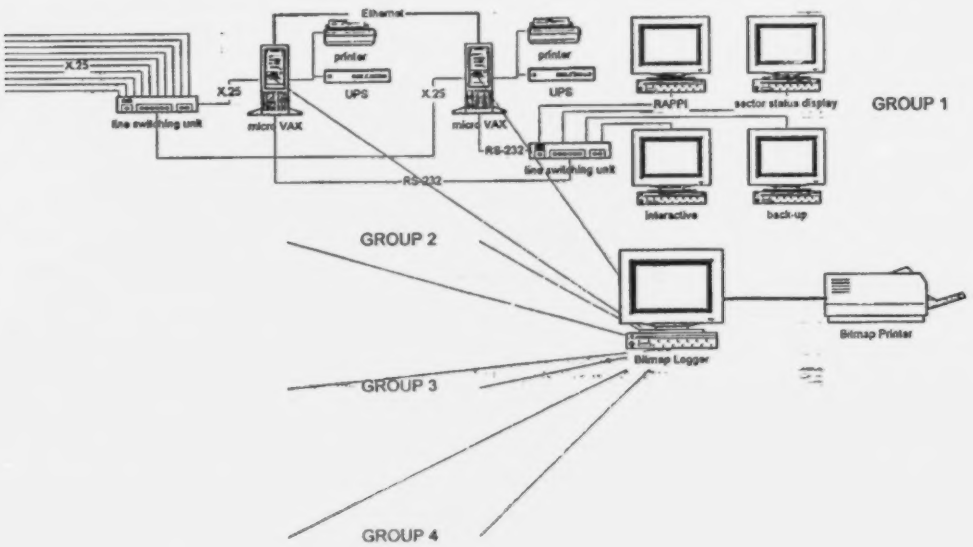

Figure 6 - Unused Serial Port Solution

The bitmap logger shall have the capability of receiving information from 8 RS-232 links. Since, there would be no need to intercept a data port, some hardware or software control flow is possible, thus facilitating the task of the bitmap logger.

3.3.1 Evaluation

MultiDev believes this is a viable option for the same reasons as those mentioned in the printer port option. However, the RCG software needs to be modified to include the bitmap port interface.

3.4 ETHERNET LINK

Another option is to use the Ethernet link between the main and the back-up computers. This link is a standard thin wire Ethernet link that transfers all the information stored on active computers. Since the back-up computer is a mirror disk of the main computer, the bitmaps stored in the main computer are transferred to the back-up computer via this link. With this link, the bitmap logger has access to all bitmaps stored onto the RCG.

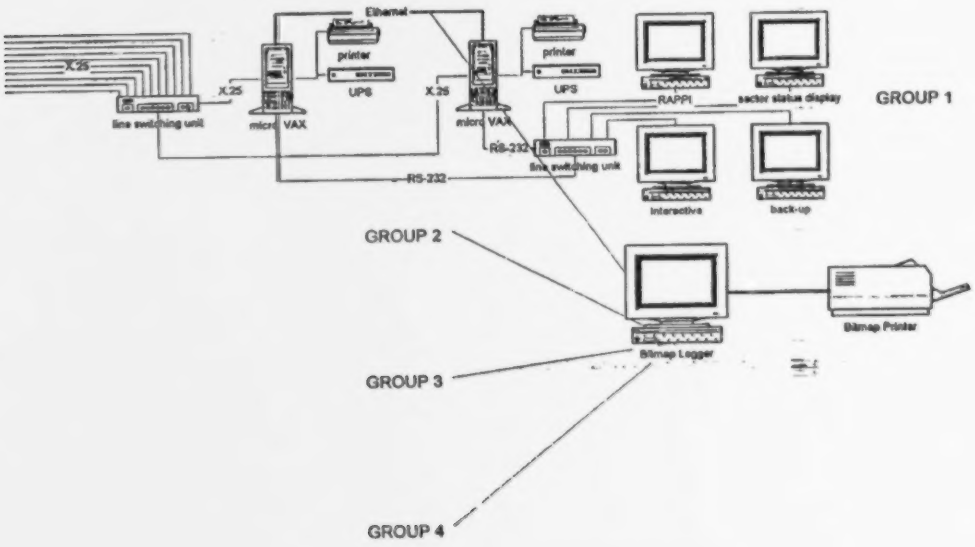

Figure 7 - Ethernet Link Solution

Contrary to the serial port options, Ethernet adds protocol information on top of the messages. The logger would have to decipher the messages in order to retrieve the bitmaps. In this case, the task of the logger is not limited to intercepting the messages, but decoding the message as well and discarding the messages that are not related to bitmaps.

The bitmap logger shall have the capability of receiving information from 4 thin wire Ethernet, without disrupting the data flow. This also means that the logger shall be able to tap the data destined to another device on the network. Since the message is not

broadcasted, the logger shall be able to read a message that has a different address than the bitmap logger.

3.4.1 Evaluation

MultiDev believes this is a viable option for the following reasons:

- The number of links and physical connections to the bitmap logger is reasonable (4).
- Since the data is tapped, the logger should intercept and store 4 simultaneous data path at once. The logger interfacing capacity will probably not be exceeded because the number of data paths is limited.
- Although the Ethernet protocol is more complex, the bitmaps can be extracted from the data stream.
- The bitmap information is complete when sent to the back-up computer.
- No software on the RCG needs to be rewritten.

3.5 X.25 TAP

Each radar site sends information to RCG and other control centres every 6 seconds. This information is sent to the RCG computer via independent X.25 links at 2400 baud. Up to 10 sites can be connected to each computer pair and there is 4 computer pairs for a total of 40 sites maximum. In order to retrieve and log bitmaps from all sites, there could be up to 40 X.25 links to tap and monitor at once. The bitmap logger would require 40 X.25 inputs to intercept all radar site bitmaps.

The X.25 link is a point-to-point connection between the communication interface equipment and the computer. Two links are provided: one for the main computer and one for the back-up computer. If the bitmap information is tapped at this point, the logger shall be able to tap each link and retrieve the information without interfering with the data flow going to the computer.

Because the communication link is limited to 2400 baud, the information is formatted such as to limit the amount of data being transmitted. Therefore, the bitmaps to be logged are only transmitted partially and some formatting would be required. For example, a fault mask is often superimposed to avoid sending the same fault pattern every 6 seconds. Therefore, a reference bitmap pattern must be kept inside the bitmap logger. Each time a new bitmap is transmitted over the X.25 link, it is superimposed with the reference pattern to produce the complete bitmap.

This means that the logger must be synchronized with the fault mask. The reference pattern must be the same as the one stored onto the main and back-up computers. Otherwise, some faults will not be shown and the bitmap logger will not display the same bitmaps as the RCG. There is a danger of losing the synchronization between the RCG and the bitmap logger.

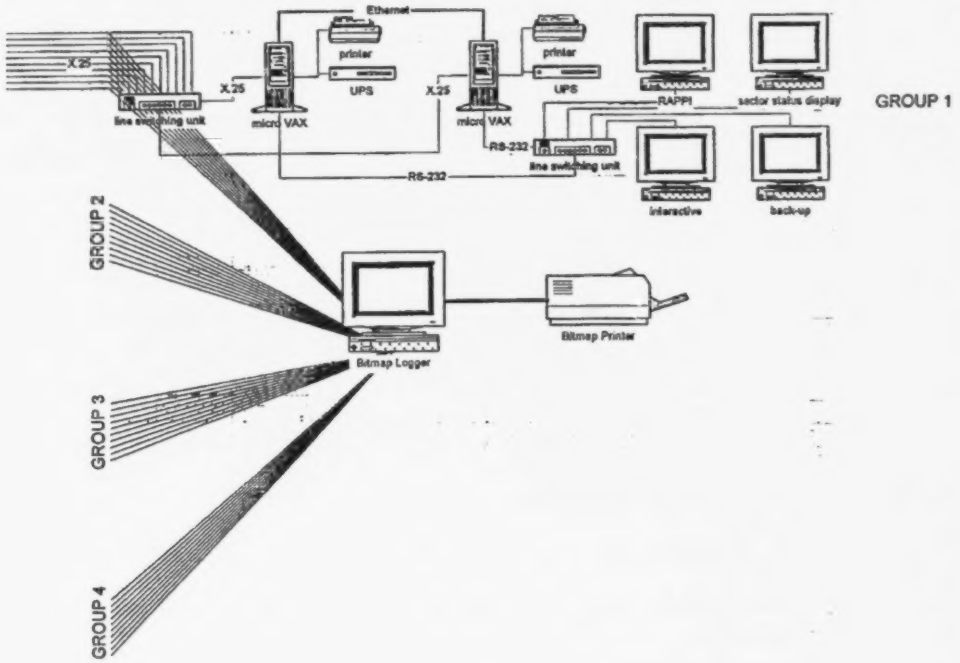

Figure 8 - X.25 Intercept Solution

The bitmap logger shall have the capability of receiving information from a maximum of 40 X.25 links, without hardware or software flow control, because it is intercepting the data flow and cannot temporarily suspend the transfers.

3.5.1 Evaluation

MultiDev believes this is not a viable option for the following reasons:

- The number of links and physical connections to the bitmap logger is too high (up to 40).
- Since data is intercepted, the logger should intercept and store up to 40 data path simultaneously. The logger interfacing capacity might be exceeded because the number of data paths is too high.
- X.25 is a point-to-point protocol. It is not designed to be easily tapped. The data flow must not be altered while intercepting the information.
- The bitmap information is not complete. The bitmap must be superimposed with the reference bitmap and there is a probability that the bitmap might be faulty.

3.6 AVAILABLE X.25 PORT

Each computer has a number of available X.25 ports in addition to the ports used for receiving the radar information. These ports are reserved as radar site back-ups and are

not presently available for other applications. However, it is possible to use one port as the transfer link to the bitmap logger. The operation is similar to any X.25 radar link, except that this port would be dedicated to the bitmap logger. The logger would not be in an intercept mode and could control the port. In this case, the logger would require only one link per computer (total of 8).

3.6.1 Evaluation

MultiDev believes this is not a viable option for the following reasons:

- The serial port option is easier to implement and requires the same effort to develop the software.
- The additional X.25 ports are presently reserved as back-ups to the radar site communications and it is not planned to allocate them to other applications.

3.7 TAPE BACK-UP PORT

Instead of using a port that is active and carries the bitmap to or from the computer, another option is to use a port that is inactive and may be available for other applications. The tape back-up port was initially added to perform regular back-ups of the RCG computer programs and data. However, this port is not regularly used anymore because the main and back-up computers exchange data and always keep a mirror image of the information.

However, this solution is not automatically implemented since the code on the main and back-up computers would have to be rewritten to duplicate the bitmap printing routines on the tape back-up port. The code would be similar to the print bitmap functions, except that the transfer to the tape port would be automatic, not on demand, each time a new bitmap is generated.

The software that was implemented for backing up the information would have to be disabled, unless it is still required in some cases. For example, if the main computer becomes faulty and only the back-up computer operates, a back-up on tape might be required at that time. This would certainly impact the operation of the bitmap logger for the duration of the computer repair period. In that case some user control would be needed to enable or disable the bitmap logger routine or the back-up routine, depending on the RCG status.

The tape port is not a widely used standard, especially for a PC. Therefore, some special interface unit would have to be purchased to interface to the bitmap logger. If such a unit is not available, an interface unit would have to be designed to connect the 8 tape port cables to the bitmap logger.

The bitmap logger shall have the capability of receiving information from 8 tape back-up port links. Since, there would be no need to intercept a data port, some hardware or software control flow is possible, thus facilitating the task of the bitmap logger.

3.7.1 Evaluation

MultiDev believes this is not a viable option for the following reasons:

- The port is not standard and special interface hardware would have to be designed.
- The computer software must be modified significantly.
- The tape back-up software and the bitmap logger software might have to be shared.
- The tape back-up software might be needed in the future and there could be a conflict with the bitmap software.

3.8 INTERFACE CARD

Finally, the last possible option is to install a new interface card dedicated to the bitmap logger. The logger would directly connect to the new card and not impact the other interface cards. The new card can be a serial port or a parallel port. Since the bitmap function does not require to transfer a large amount of information, it is easier to install a new serial port interface card.

Since there are no slots available, the tape back-up port could be removed from the computer. The driver for the new board would have to be installed. New software similar to the unused serial port option would have to be developed. Some hardware modifications to the system might be required.

Since the new card function is similar to the unused serial port option, there is no real benefit to this option other than not impacting the existing interfaces. However, if the tape port is required at some point in time, this option is not achievable.

The bitmap logger have the capability of receiving information from 8 serial links. Since, there would be no need to intercept a data port, some hardware or software control flow is possible, thus facilitating the task of the bitmap logger.

3.8.1 Evaluation

MultiDev believes this is not a valid option for the following reasons:

- The addition of a new card does not provide any benefit over the utilization of an unused serial port.
- The bit rate is too low to justify the use of a high-speed interface board.
- The tape back-up card must be replaced, thus eliminating back-ups and software reloads.

4. RISKS

The RCG operates in a critical environment and, as such, shall not be altered by any other piece of equipment that connects to it. This section performs a risk analysis of the solutions for implementing a bitmap logger that will connect to the RCG. Many criteria have been selected for this analysis and they all have this common consideration: the possibility of altering the actual functionality of the RCG. The three solutions retained in sections 3.2, 3.3 and 3.4 are analyzed with respect to each criteria listed below.

4.1 SYSTEM INTEGRITY

In order to maintain system integrity, any modification to the RCG shall not alter its capability to perform present operations and keep the same functionality as it was originally designed for. This includes the addition of new software or new hardware, modifications to the software or hardware, connections to the data links, connections to the unused ports, and modifications to the user interface.

The first printer port solution (the printer cable is tapped) will require intercepting the data traveling through the printer serial cable. This operation is fairly safe as long as the bitmap logger does not connect to the receive line of the RCG computer. Therefore, no data can unintentionally be sent to the computer.

In the second printer port solution (the logger connects between the computer and the printer), the bitmap logger redirects the printer data being sent to the printer and the printer status being sent to the computer. Because the logger receives the printer information from one serial port and retransmits it to another serial port, there is a chance that the logger may corrupt the bit stream.

The software is another area where the system integrity might be altered. Presently, the RCG does not automatically print the bitmaps. This operation must be performed by an operator. If this action shall become automatic, the RCG software has to be modified to automatically send the data to the printer port. The addition of new software is a risk to system integrity.

The unused serial port solution removes the interfacing problems associated with the printer port; the unused port can be configured to send bitmaps only and not receive any data. However, the software modifications are more complex. The new software duplicates the printer port function for printing bitmaps. Of course, this function will automatically download through the serial port every time a new bitmap is received by the RCG computer.

The Ethernet solution does not require any modification to the software and to the hardware. Ethernet links are multipoint by nature and are designed to provide multiple connections. Adding a new link such as the bitmap logger will not impact the system integrity as long as the logger is prevented from sending any data over the Ethernet link.

The table below lists the criterias versus a particular solution that could modify and impact system integrity.

Table 1 - Criteria Used to Analyze the RCG Integrity

	Printer Port	Unused Port	Ethernet Link
RCG Software	√	√	
RCG Data	√		
RCG Hardware			
User Interface	√		
Data Links	√		√

4.2 SYSTEM SECURITY

To maintain system security, any new hardware or software used for implementing new functions shall not be able to modify the system functionality and operations, other than the purpose for which the new function is being added. The new function shall not permit a user to enter the system in a new manner unless this is specified in the new function.

The printer port solution does not impact the system security since only data returning to the RCG computer is the printer status information. If a user tries to enter another type of data, the information will be discarded as being invalid data.

The unused serial port provides a better protection since the new software will be designed to ignore any data being received.

The Ethernet solution could provide a means for a user to enter the system. Therefore, no code on the bitmap logger shall be able to transmit on Ethernet.

In all cases, the bitmap logger shall not have any function that allows a user to talk to a RCG computer. Since the bitmap acquisition is automatic at the logger end, all functions that a user has access to concern the printer, the storage, the retrieval, the display and the analysis of the bitmaps. Therefore, no functions are planned to interact with a RCG computer.

The table below lists the criterias versus a particular solution that could modify and impact system security.

Table 2 - Criteria Used to Analyze the RCG Security

	Printer Port	Unused Port	Ethernet Link
RCG Software	√	√	
RCG Data	√		
User Interface	√		
Data Links	√		√

4.3 SYSTEM RELIABILITY

System reliability addresses many issues and is more subtle to define. Many elements might be impacted when adding the bitmap transfer function:

1. The CPU time of the RCG computer might increase, thus reducing the safety margin required to safely operate the computer software.
2. The computer software might be modified. This means that new programs will be integrated and may cause a system degradation or failure. This could also mean loss of data or, in the worst case, malfunction of the radars caused by the RCG.
3. The new hardware could reduce the MTBF or the life cycle of the system.

The first printer port solution (tapping the line) is fairly safe in the sense that it does not change the system configuration and the logger is totally passive with respect to the RCG computer operations.

The second printer port solution (between the printer and the computer) could stop or degrade the printing operation and prevent the computer from receiving the printer status information. This solution is more hazardous.

For both printer port solutions, the addition of new software to render the printing function automatic will impact the first two reliability issues mentioned above. The change in the CPU time will be minimal, but the software reliability will be reduced when the automatic printing program is added.

The unused serial port solution will increase the CPU time and will duplicate the printing function for the bitmaps, thus reducing the system reliability.

The Ethernet solution does not impact the system reliability since the logger connects to the Ethernet link and does not require new software or hardware. However, the bitmap logger should be prevented from talking over the Ethernet link.

The table below lists the criterias versus a particular solution that could modify and impact system reliability.

Table 3 - Criteria Used to Analyze the RCG Reliability

	Printer Port	Unused Port	Ethernet Link
CPU Effort	√	√	
RCG Software	√	√	
RCG Data	√		
RCG Hardware			
User Interface	√		
Data Links	√		√

4.4 BITMAP LOGGER IMPLEMENTATION

The risks associated with the implementation of the bitmap logger are mainly in the extraction of the bitmaps from the data streams and providing a reliable interface to all data streams at once. The three retained solutions provided in this document are of different complexity levels.

4.4.1 Bitmap Data Stream Extraction

The printer port solution is the easiest to implement since the bitmaps being sent over the serial link are exactly in the format requested by the logger. The information is easy to extract (in ASCII format) and can be easily stored and sorted. The difficulty lies in the implementation of the automatic print function within the RCG computer.

The unused serial port solution will provide the same type of data to the logger. However, the software implementation is more complex than the printer port since the bitmap print function must be duplicated within the RCG computer.

The Ethernet solution is the most complex of all. Firstly, it is not known if the bitmaps being exchanged between the main and the back-up computers have the same format as those generated over the printer port. A data extraction and conversion operation might be necessary. Secondly, the Ethernet protocol must be removed from the data stream and only the bitmap data needs to be localized and extracted from the Ethernet envelope. Thirdly, the RCG is designed to let the data stream flow between the main and the back-up computers. The packet addresses are for those computers only and the logger shall be able to tap the line and read all the information although it is not destined to it.

4.4.2 Bitmap Logger Hardware

The bitmap logger hardware differs, depending on the retained solution. The Printer port and the unused serial port solutions require eight serial ports, two for each of the four RCG computer pairs. The Ethernet solution requires four Ethernet ports, one for each RCG computer pair. The logger shall be able to handle four Ethernet links, or eight serial ports, transmitting at the same time in the worst case. Handling 8 serial ports operating at 9600 baud is easier than handling four Ethernet links operating at 10 Mb/sec.

For the retained solution, the logger shall be able to receive bitstreams in parallel, read all the information, detect the bitmap data, extract the bitmap data from the bit stream, and store it.

4.4.3 Bitmap Logger Operation Software

The logger software will be the same for all solutions and does not increase the risk of one particular solution. The overall operations consist of reading, storing, printing and analyzing the bitmaps, providing a bitmap search tool, and providing a back-up capability.

4.5 BITMAP LOGGER COMPLEXITY

The bitmap logger complexity is related to the operations that a user will have to perform in order to operate and maintain the logger. This also includes training, the learning curve, system maintenance and repair, and software maintenance. With respect to the system complexity, all solutions appear relatively similar in terms of risks.

In general, once the bitmap logger is developed, the system operation and maintenance should be fairly simple, since the functionality is exclusively developed for bitmap operations. The reading, printing, storing and back-up operations are relatively simple to perform. The bitmap analysis and search tool are more complex but are limited to software implementations.

Bitmap logger maintenance is easier than maintaining a RCG computer because the solution will be PC based, using off-the-shelf components, easy to fix and to replace.

5. COSTS

The costs associated with the implementation of a bitmap logger are twofold: the acquisition costs and the maintenance costs. The acquisition costs include the initial purchase of the equipment and the NRE costs: the specifications, the design, the implementation of the software and the testing phase. The maintenance costs include the fees to maintain the hardware and update the software. The maintenance costs may be in the form of an annual maintenance fee with the bitmap logger development company.

5.1 ACQUISITION COSTS

The acquisition costs are listed in the sections below.

5.1.1 Equipment

The equipment is composed of a regular PC, with sufficient capacity to store all the bitmaps, and with a reliable back-up capability. Also, the appropriate interface to accept the bitmap data must be purchased.

The hard disk capacity is estimated to be:

$$capacity = \frac{25 bitmaps *}{week} \cdot \frac{500 bytes **}{site \cdot bitmap} \cdot 15 years \cdot 40 sites \approx 400\ MB$$

* 25 bitmaps/week is an estimated average of the bitmaps generated by each site.
** a report will be composed of 366 bytes for the bitmap plus overhead for the data base.

A 2.5 GB hard disk could easily handle all bitmaps being stored on the logger for a period of 15 years and, at the same time, contain the software and the other functions required to operate the logger.

Table 4 - Equipment Costs

ITEM	COST
PC	$2,500
Hard Disk	$1,000
8 Serial Ports with high speed buffers (or 4 Ethernet links)	$1,500
Tape Back-Up Unit	$1,500
Back-Up Tapes	$2,000
Printer	$1,500
TOTAL	$10,000

The implementation costs include the normal development costs listed in the tables below. Table 5 shows the costs for implementing the serial port (printer or unused port) solutions while shows the costs for implementing the Ethernet solution.

Table 5 - Serial Port Solution, NRE Costs

ITEM	LEVEL OF EFFORT	COST
Specifications	10 person-days	$4,000
GUI Design	10 person-days	$4,000
GUI Implementation	20 person-days	$8,000
Applications Software Design	20 person-days	$8,000
Applications Software Implementation	30 person-days	$12,000
Serial Port Interface Design	5 person-days	$2,000
Serial Port Interface Implementation	10 person-days	$4,000
Debugging	20 person-days	$8,000
Testing	15 person-days	$6,000
Integration	15 person-days	$6,000
TOTAL	155 person-days	$62,000

Table 6 - Ethernet Solution, NRE Costs

ITEM	LEVEL OF EFFORT	COST
Specifications	10 person-days	$4,000
GUI Design	10 person-days	$4,000
GUI Implementation	20 person-days	$8,000
Applications Software Design	20 person-days	$8,000
Applications Software Implementation	30 person-days	$12,000
Ethernet Port Interface Design	10 person-days	$4,000
Ethernet Port Interface Implementation	25 person-days	$10,000
Debugging	20 person-days	$8,000
Testing	15 person-days	$6,000
Integration	15 person-days	$6,000
TOTAL	175 person-days	$70,000

The Ethernet solution is more expensive because software has to be developed to receive information traveling at high-speed through the link, remove the protocol, detect the bitmaps and extract them while the serial port is already sending the final bitmap format.

5.2 MAINTENANCE COSTS

Maintenance costs can be estimated to be 10% of the acquisition costs, which would include in this case the cost of the applications software ($10,000). An annual fee of $2,000 would cover the service contract.

6. COMPARATIVE ANALYSIS

6.1 METHODOLOGY

The multicriteria comparative analysis tries to determine which solution offers the best alternative to implement a bitmap logger, based on the criteria described in the above sections. Each criteria is given a weight, depending on its critical aspect, the risks of implementing the solution, and its impact on the bitmap logger implementation.

The criteria will be presented in the form of a table. The totals will be shown at the bottom of the table. Section 7 presents the final recommendation of this document.

This method provides an easy technique to perform a one-on-one comparison between the criteria and between the solutions. By having a multi-level criteria evaluation, the weights are distributed on one, two or three items at each sub-level, thus facilitating their comparison. The end result is a more thorough analysis of each criteria and their importance in the evaluation, instead of assigning weights to multiple criteria at once.

The multicriteria evaluation is presented in this section. An in-depth evaluation of the criteria based on the Analytic Hierarchy Process[3] is also included in Appendix B. The second method comfirms the results of this section.

6.2 OBJECTIVES

The multicriteria analysis is performed using a hierarchy of objectives describing the values to be considered in the evaluation of the overall objective[2]. Each sub-level is given weights, totalling 1.00 at each sub-level for each category. Sub-levels are added until the final criteria selected in the previous sections are obtained. Finally, the selected criteria are given weights by multiplying all the weights of its tree. These weights are used in Table 7 to do the final comparison.

Figure 9 shows the hierarchy of the multicriteria comparative analysis.

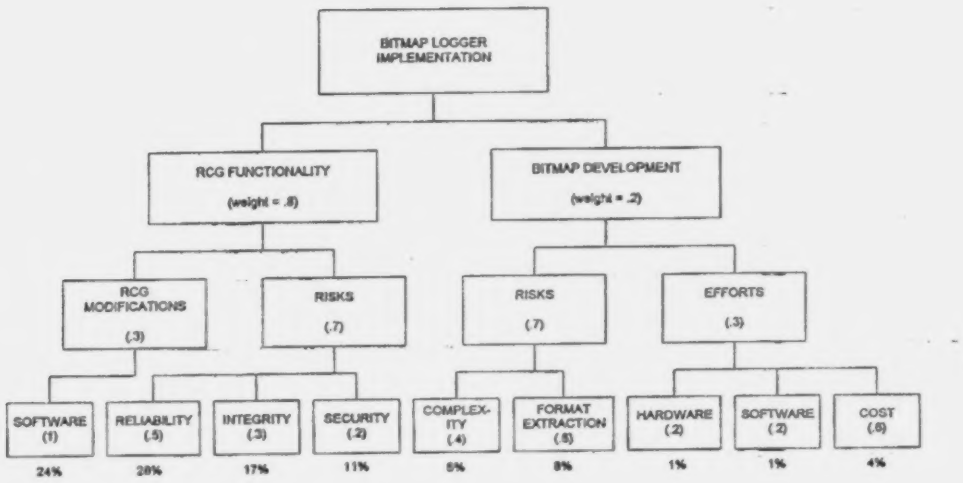

Figure 9 - Hierarchy for the Evaluation of the Bitmap Logger Implementation

6.3 SELECTED CRITERIA

Nine criteria have been retained for the evaluation of the viable solutions. They are:

1. **RCG Software Modifications.** The necessity to modify the RCG code in order to implement the bitmap logging function.
2. **RCG Reliability.** The risks of reducing the life cycle of the RCG, degrade the software operations or make the system fail because of software bugs.
3. **RCG Integrity.** The risks of altering the operations and the functionality of the RCG.
4. **RCG Security.** The risks of allowing an external user to enter the RCG operations and extract data or alter the RCG data.
5. **Bitmap Logger Complexity.** The difficulty to implement and operate the bitmap logger.
6. **Bitmap Format Extraction.** The difficulty to extract or reconstruct the bitmaps from the information sources.
7. **Bitmap Logger Software Implementation.** The level of effort required to implement the bitmap logger software.
8. **Bitmap Logger Hardware Implementation.** The level of effort required to implement the bitmap logger hardware.
9. **Costs.** The equipment, implementation and maintenance costs.

6.4 MULTICRITERIA ANALYSIS

Table 7 - Multicriteria Analysis Comparison

CRITERIA	PRINTER PORT (1ST SOLUTION)	PRINTER PORT (2ND SOLUTION)	UNUSED PORT	ETHERNET
RCG Software Mods (24 points)	0.75	0.75	0.50	1.00
RCG Reliability (28 points)	0.80	0.67	0.67	0.87
RCG Integrity (17 points)	0.67	0.67	0.80	1.00
RCG Security (11 points)	1.00	1.00	0.87	0.87
Logger Complexity (6 points)	0.80	0.80	1.00	0.50
Format Extraction (8 points)	0.90	0.90	1.00	0.50
Hardware Impl. (1 point)	0.70	0.60	0.75	0.80
Software Impl. (1 point)	0.70	0.65	0.70	0.55
Costs (4 points)	1.00	1.00	1.00	0.75
TOTAL (100 points)	**80.19**	**76.40**	**73.38**	**86.28**
Weight	**.2536**	**.2416**	**.2320**	**.2728**
Rank	**2**	**3**	**4**	**1**

The weights have been assigned based on MultiDev's knowledge of the RCG system. The values might change based on additional information and the evaluation given by other personnel involved in the direction, operation and maintenance of the bitmap logger. For example, the software modifications to the RCG could be a major concern in the evaluation process such that the solutions requiring software modifications might be discarded.

7. RECOMMENDATIONS

Three solutions out of 4 have scored close to each other. The only solution that scored lower is the unused serial port solution, mainly due to the RCG software modifications which are more important in this case. The printer port solution is attractive if RCG software modifications can be implemented. The solution that scored the highest, the Ethernet link solution, is the only solution that does not require any change to the RCG software.

The printer port solution is probably the easiest to implement. The bitmaps are already formatted, the transfer rate on each serial port is low, which allows the bitmap logger to intercept the data and store it in real-time. However, the RCG software shall be modified to automate the printing process and send all bitmaps to the logger.

The unused port is slightly harder to implement, but its major drawback is the amount of software that needs to be added to the RCG. Since a new function will be implemented, this will have an impact on system reliability. At the other end, the bitmap logger interface and functionality would be the same as for the printer port.

The Ethernet link offers the best solution. It does not require any software modifications to the RCG. However, it is more complex to implement. Four Ethernet links need to be tapped in real-time, with the capability of reading all information, remove the protocols and extract the bitmaps from the data streams. An efficient interface can be achieved with Pentium PC which are now able to handle multiple data streams such as four Ethernet ports (4 x 10 Mb/sec).

8. REFERENCES

[1] *Radar Set AN/FPS-124(V) Combined Operation and Maintenance Manual*, Unisys Corporation, April 1994.

[2] Jean-Paul Paquin and Raymond Paquin, *Multicriteria Analysis: Evaluating a Portfolio of Public Enterprises*, Evaluation Methods Sourcebook, pp. 126-149.

[3] Saul I. Gass, *The Analytic Hierarchy Process*, Decision Making, Models and Algorithms, pp. 355-367.

APPENDIX A - BITMAP REPORT

SITE LAB-1 SITE ID OD CH. NO. 3 OPERATOR REQUESTED

TEST BIT PATTERN REPORT

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SP INPUT MEMORY TEST BITS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SP PULSE COMPRESSION TEST BITS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SP DOPPLER FILTER TEST BITS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SITE LAB-1 SITE ID OD CH. NO. 3 OPERATOR REQUESTED

TEST BIT PATTERN REPORT

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SP DETECTION PROCESSING TEST BITS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SP TIMING AND I/O TEST BITS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SITE LAB-1 SITE ID 0D CH. NO. 3 OPERATOR REQUESTED

REPORT NO. 196 TEST BIT PATTERN REPORT 24 JAN 1996 21:35 PAGE 3 OF 7

POWER SUPPLY TEST BITS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

FAN/BLOWER TEST BITS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-						
3	-	-														

FREQUENCY SOURCE TEST GROUP A TEST BITS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-															

RECEIVER TEST BITS

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-

DRIVER, POWER MONITOR, FS PHASE CONTROL, MTI, VALID/INVALID TEST BITS

	1	2	3	4	5	6	7	8	9
1	-	-	-	-	-	-	-	-	-

SITE LAB-1 SITE ID OD CH. NO. 3 OPERATOR REQUESTED

TEST BIT PATTERN REPORT

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SCR SUM CHANNEL TEST BITS

	1 2 3 4 5 6 7 8 9	1 0	1 1	1 2	1 3	1 4	1 5	1 6	1 7	1 8	1 9	2 0	2 1	2 2	2 3	2 4	2 5	2 6	2 7	2 8	2 9	3 0
1					-	-	-	-	-	-	-												
2	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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24	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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26	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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36	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	- - - - - - - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SITE LAB-1 SITE ID 0D CH. NO. 3 OPERATOR REQUESTED

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SCR DELTA CHANNEL TEST BITS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

POWER OUTPUT TEST BITS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	-	-	-	-	-	-	-	#	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#	-	-			
2								-	-	-	-	-	-	-	-	-	-	-	#	-	-	-	-	-								
3			-	-	-	-	-	-	-	-	-	-	-	#	-	-	-	#	-	-	-	-										

DUAL CHANNEL RECEIVER TEST BITS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-
6	-	-	-	-	-	-
7	-	-	-	-	-	-
8	-	-	-	-	-	-
9	-	-	-	-	-	-
10	-	-	-	-	-	-
11	-	-	-	-	-	-
12	-	-	-	-	-	-

SITE LAB-1 SITE ID OD CH. NO. 3 OPERATOR REQUESTED

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BEAM SWITCH NUMBERS

1	51	31	46	26
37	17	67	12	62
3	53	33	48	28
39	19	69	14	64
5	55	35	50	30
41	21	71	16	66
7	57	2	52	32
43	23	38	18	68
9	59	4	54	34
45	25	40	20	70
11	61	6	56	36
47	27	42	22	72
13	63	8	58	
49	29	44	24	
15	65	10	60	

BEAM SWITCH TEST BITS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

BSU COMPARATOR AND CONFIGURATION TEST BITS

	1	2	3	4	5	6
1	-	-	-	-	-	-

OLTR-BSU, DDA, FS, RCVR, SR

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SITE LAB-1 SITE ID OD CH. NO. 3 OPERATOR REQUESTED

TEST BIT PATTERN REPORT
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LRU'S 1A201 - 1A236 T/R MODULE TEST BITS

```
                                1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3
    1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6
  1 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  2 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  3 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  4 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  5 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  6 -
      1   2   2   2   2   2   2   2   2   2 1 2 1 2 1 3 1 3 1 3 1 3 1 3 1 3 1 3
LRU 1 9 2 0 3 1 4 2 5 3 6 4 7 5 8 6 9 7 0 8 1 9 2 0 3 1 4 2 5 3 6 4 7 5 8 6
```

LRU'S 1A201 - 1A236 T/R MODULE CURRENT PULSE TEST BITS

```
                                1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3
    1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6
  1 - - - - - - - # - - - - - - - - - - - - - - - - - - - - # - - - - - - - -
  2 - - - - - - - # - - - - - - - - - - - - - - - - - - - - # - - - - - - - -
                  1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3
LRU 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6
```

LRU'S 2A2A1 - 2A2A11 AZIMUTH COMMUTATOR TEST BITS

```
                  1 1
    1 2 3 4 5 6 7 8 9 0 1
  1 - - - - - - - - - - -
  2 - - - - - - - - - - -
  3 - - - - - - - - - - -
  4 - - - - - - - - - - -
  5 - - - - - - - - - - -
  6 - - - - - - - - - - -
                  1   1
LRU 1 7 2 8 3 9 4 0 5 1 6
```

APPENDIX B - ANALYTIC HIERARCHY PROCESS

The Analytic Hierarchy Process is a tool capable of performing an in-depth comparison of the criteria and the solutions retained for the evaluation. The first step is to compare each criteria on a one-on-one basis, giving a weight that represents the importance of the criteria in the row with respect to the criteria in the column. This produces a symetrical matrix: the elements above the diagonal (named x_{ij}) are inversely proportional to the elements below the diagonal (which equal $1/x_{ji}$).

The first result at the end of the table is $\prod_i$ which is the product of the weights. The second result is P_i, the cubic root of $\prod_i$. The last column is P_i/P, P being the sum of all P_i. The final result is a weight representing the relative importance of each criteria in the final evaluation. The sum of all P_i/P is 1.

TABLE 1 - CRITERIA COMPARISON

CRITERIA		1	2	3	4	5	6	7	8	9	Πi	Pi	Pi/P
1	RCG S/W	1	0.75	1.5	1.5	2	2	2.5	2.5	2	84.375	4.386027	0.264179
2	RELIABILITY	1.333333	1	1.5	1.5	2	2	2.5	2.5	2	150	5.313293	0.32003
3	INTEGRITY	0.666667	0.666667	1	1.5	2	1.5	2	2	2	16	2.519842	0.151775
4	SECURITY	0.666667	0.666667	0.666667	1	2	1.5	2	2	2	7.111111	1.922999	0.115826
5	COMPLEXITY	0.5	0.5	0.5	0.5	1	0.5	1	1	0.5	0.015625	0.25	0.015058
6	FORMAT	0.5	0.5	0.666667	0.666667	2	1	2	2	2	1.777778	1.211414	0.072966
7	BITMAP H/W	0.4	0.4	0.5	0.5	1	0.5	1	1.5	1	0.03	0.310723	0.018715
8	BITMAP S/W	0.4	0.4	0.5	0.5	1	0.5	0.666667	1	0.5	0.006667	0.188207	0.011336
9	COST	0.5	0.5	0.5	0.5	2	0.5	1	2	1	0.125	0.5	0.030116
SUM												16.60251	1

The following nine tables perform a comparison of individual criteria for each solution. Each solution is compared with each other solution with respect to its importance for a particular criteria. Weights similar to Table 1 are produced.

TABLE 2 - SOLUTION COMPARISON FOR THE RCG SOFTWARE

SOLUTION		1	2	3	4	Πi	Pi	Pi/P
1	PRINTER PORT 1	1	1	1.3	0.5	0.65	0.866239	0.188149
2	PRINTER PORT 2	1	1	1.3	0.5	0.65	0.866239	0.188149
3	UNUSED PORT	0.769231	0.769231	1	0.333333	0.197239	0.5821	0.126433
4	ETHERNET	2	2	3	1	12	2.289428	0.497269
SUM							4.604006	1

TABLE 3 - SOLUTION COMPARISON FOR THE RCG RELIABILITY

SOLUTION		1	2	3	4	Πi	Pi	Pi/P
1	PRINTER PORT 1	1	1.5	0.8	1.333333	1.6	1.169607	0.288872
2	PRINTER PORT 2	0.666667	1	2.5	0.75	1.25	1.077217	0.266053
3	UNUSED PORT	1.25	0.4	1	0.9	0.45	0.766309	0.189265
4	ETHERNET	0.75	1.333333	1.111111	1	1.111111	1.035744	0.25581
SUM							4.048878	1

TABLE 4 - SOLUTION COMPARISON FOR THE RCG INTEGRITY								
SOLUTION		1	2	3	4	Πi	Pi	Pi/P
1	PRINTER PORT 1	1	1	1.5	1	1.5	1.144714	0.275499
2	PRINTER PORT 2	1	1	1.5	1	1.5	1.144714	0.275499
3	UNUSED PORT	0.666667	0.666667	1	0.5	0.222222	0.605707	0.145776
4	ETHERNET	1	1	2	1	2	1.259921	0.303226
SUM							4.155056	1

TABLE 5 - SOLUTION COMPARISON FOR THE RCG SECURITY								
SOLUTION		1	2	3	4	Πi	Pi	Pi/P
1	PRINTER PORT 1	1	2	0.8	1.5	2.4	1.338866	0.329385
2	PRINTER PORT 2	0.5	1	0.666667	2	0.666667	0.87358	0.214916
3	UNUSED PORT	1.25	1.5	1	0.5	0.9375	0.978717	0.240782
4	ETHERNET	0.666667	0.5	2	1	0.666667	0.87358	0.214916
SUM							4.064744	1

TABLE 6 - SOLUTION COMPARISON FOR THE BITMAP COMPLEXITY								
SOLUTION		1	2	3	4	Πi	Pi	Pi/P
1	PRINTER PORT 1	1	2	1	2	4	1.587401	0.357948
2	PRINTER PORT 2	0.5	1	0.5	1	0.25	0.629961	0.142052
3	UNUSED PORT	1	2	1	2	4	1.587401	0.357948
4	ETHERNET	0.5	1	0.5	1	0.25	0.629961	0.142052
SUM							4.434723	1

TABLE 7 - SOLUTION COMPARISON FOR THE BITMAP FORMAT EXTRACTION								
SOLUTION		1	2	3	4	Πi	Pi	Pi/P
1	PRINTER PORT 1	1	1	1	3	3	1.44225	0.30949
2	PRINTER PORT 2	1	1	1	3	3	1.44225	0.30949
3	UNUSED PORT	1	1	1	3	3	1.44225	0.30949
4	ETHERNET	0.333333	0.333333	0.333333	1	0.037037	0.333333	0.071529
SUM							4.660082	1

TABLE 8 - SOLUTION COMPARISON FOR THE HARDWARE IMPLEMENTATION								
SOLUTION		1	2	3	4	Πi	Pi	Pi/P
1	PRINTER PORT 1	1	1.5	1	0.75	1.125	1.040042	0.244063
2	PRINTER PORT 2	0.666667	1	0.5	0.5	0.166667	0.550321	0.129142
3	UNUSED PORT	1	2	1	0.75	1.5	1.144714	0.268626
4	ETHERNET	1.333333	2	1.333333	1	3.555556	1.526286	0.358168
SUM							4.261363	1

TABLE 9 - SOLUTION COMPARISON FOR THE SOFTWARE IMPLEMENTATION								
SOLUTION		1	2	3	4	Πi	Pi	Pi/P
1	PRINTER PORT 1	1	2	1	2.5	5	1.709976	0.372558
2	PRINTER PORT 2	0.5	1	0.5	0.75	0.1875	0.572357	0.124701
3	UNUSED PORT	1	2	1	2.5	5	1.709976	0.372558
4	ETHERNET	0.4	1.333333	0.4	1	0.213333	0.597521	0.130184
SUM							4.58983	1

TABLE 10 - SOLUTION COMPARISON FOR THE BITMAP IMPLEMENTATION COSTS								
SOLUTION		1	2	3	4	Πi	Pi	PI/P
1	PRINTER PORT 1	1	1	1	1.13	1.13	1.04158	0.259765
2	PRINTER PORT 2	1	1	1	1.13	1.13	1.04158	0.259765
3	UNUSED PORT	1	1	1	1.13	1.13	1.04158	0.259765
4	ETHERNET	0.884956	0.884956	0.884956	1	0.69305	0.884956	0.220704
SUM							4.009697	1

The last table combines the criteria comparison table and the solution comparison tables. The final comparison weights are computed as follows:

$$PI = \sum_{j=1,9} a_j \bullet b_{ij}, \quad i = solution\ number, \quad j = criteria\ number$$

where: $a_j = criteria\ weight$ and $b_{ij} = solution\ weight$

TABLE 11 - MULTICRITERIA COMPARISON												
	CRITERIA →	1	2	3	4	5	6	7	8	9		
SOLUTION		RCG S/W	RELIABILITY	INTEGRITY	SECURITY	COMPLEXITY	FORMAT	BITMAP H/W	BITMAP S/W	COST	PI	RANK
	TABLE 1 WEIGHTS	0.163058	0.717876	0.050457	0.030562	0.00382	0.019672	0.004813	0.002649	0.007093		
1	PRINTER PORT 1	0.188149	0.288872	0.275499	0.329385	0.357948	0.30949	0.244063	0.372558	0.259765	0.273481	2
2	PRINTER PORT 2	0.188149	0.266053	0.275499	0.214916	0.142052	0.30949	0.129142	0.124701	0.259765	0.251567	3
3	UNUSED PORT	0.126433	0.189265	0.145776	0.240782	0.357948	0.30949	0.268626	0.372558	0.259765	0.182777	4
4	ETHERNET	0.497269	0.25581	0.303226	0.214916	0.142052	0.071529	0.358168	0.130184	0.220704	0.292176	1
SUM											1	

Although the results are slightly different, they still confirm the rank of each solution as listed in the multicriteria analysis section (section 6.4).

	MULTICRITERIA COMPARISON		ANALYTIC HIERARCHY PROCESS	
	SCORE	RANK	SCORE	RANK
Printer Port 1	.2536	2	.2735	2
Printer Port 2	.2416	3	.2516	3
Unused Port	.2320	4	.1828	4
Ethernet	.2728	1	.2922	1

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The monitoring of the various radar sites is performed with automatic test equipment located at each site. Data from various sensors and monitoring points within the radar is acquired locally and transferred to the ROCC through RF and telecommunications links. Acquired data consists of multiple data streams, tables, and other status reports presented on computer monitors, stored in RCG local memory and on disk, and archived on tape or printed on paper. Of all these reports, one is a bitmap providing a graphical status representation of the multiple electronic components within the radar. The bitmap provides valuable information on the radar functional status and on the corrective actions to be taken.

The bitmaps are received at the ROCC and stored in RCG local memory. The memory has a first in first out buffer that can hold up to 64 bitmaps per site. Once the buffer reaches its full capacity, bitmaps are lost. This can be a major inconvenience if an event must be traced back in which case there is a significant probability that the required bitmap is lost if the request to print comes too late.

The Department of National Defence is interested in logging all bitmaps at the ROCC for future retrieval. This would eliminate the loss of critical information and simplify diagnostics of the radar. The goal of this document is to explore the various ways in which the bitmap data could be logged and formulate recommendations.

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BITMAP LOGGER
RELIABILITY
INTEGRITY
SECURITY
PRINTER
ETHERNET
TEST BIT PATTERN
LOGISTICS SUPPORT SITE (LSS)
PREVENTIVE MAINTENANCE INSPECTION (PMI)
TEMPERATURE

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